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Analysis of Morphometric Traits and Ecological Threats in Stubbs Creek Forest Reserve, Akwa Ibom State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted in Stubbs Creek Forest Reserve, (SCFR) Akwa Ibom State, Nigeria. The aim was to analyse the morphometric traits of this area, using some relevant terrain attributes (elevation, slope and aspect) in ascertaining areas threatened by significant ecological problems such as flood, erosion and others. In terms of method of study, a digital elevation model (DEM) was purchased as a raster with longitude and latitude; geo-referenced, but re-projected to WGS, UTM zone 32 N in order to enhance data integration into the GIS interfaces. The surface operation tool of ArcGIS 9.3 spatial analyst extension was used to extract the different layers being elevation, slope and aspect. These were subjected to reclassification function in the same software to harmonise

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the units of measurement for integration into the same analysis environment. After reclassification, the layers were taken to map algebra environment to model erosion, flood hazards and possibility of siltation of streams, tributaries and wetlands in this area. Consequently, slope, elevation and aspect were the surface layers utilized for the single output map algebra. The result confirmed the elevation of this area to be low-lying altitude above the mean sea level with Open Water, Sea Level Terrain, Beach Ridge Complex, Alluvial Plain Sands with Mangroves and Gently Undulating Coastal Plain Sands as the five significant terrain classes in SCFR. The result further revealed that areas without adequate vegetation cover recorded series of ecological hitches than areas with adequate vegetation cover. Specifically, the identified problems included water pollution, coastal erosion, land degradation, soil contamination, flood, habitat fragmentation, distortion of wetlands and siltation of streams, rills and tributaries which restriction of anthropogenic activities and adequate restoration measures in SCFR are strongly recommended for its sustainability.

Keywords: Digital elevation model; terrain classes; ecological hitches.

1. INTRODUCTION

Morphometry is the science of the estimation of dimensions as well as the mathematical approach in determining the earth's configuration, shape, surface and morphometric properties which lead to the comprehension of flood, sediment yield and diverse ecological hitches [1]. For example, Rao and Yusuf [2] used remote sensing and geographic information systems (GIS) to conduct a morphometric analysis of soil erosion in a portion of the Chambal Basin, likewise Biswas and Biswas [3] who examined the morphometric characteristics of the Lokjurija River Basin for its changing pattern of land use cover from 1989 to 2014, whose findings revealed that the lower portion of the River Basin experienced significant and uneven urban growth, while the middle and upper portions showed dense forest. Also, Enokela et al. [4], assessed the severity and associated economic losses by analyzing the morphometric characteristics of four gullies in the Katsina-Ala Local Government Area of Benue State. Accordingly, Eze and Effiong [5] investigated the Calabar River Basin's morphometric parameters to justify their implications for the hydrologic process, while Ezenwaji et al. [6] understudied the morphometric characteristics of the Obibia Drainage Basin in Awka Urban Area of Anambra State, Nigeria. Equally, Pal and Debnath [7] examined the morphometric characteristics of the upper part of the Dwarkeswar Watershed by measuring basic, linear, areal, and relief aspects of the watershed with nearly 20 morphometric parameters. The results of the aforementioned researches helped in understanding and finding solutions to the environmental and ecological problems which confronted the said areas. As opined by Wainright and Brazier [8], assessment of morphometric parameters helps in determining the nature of the surface of the earth (topography of an area).

The velocity at which surface runoff flows and its erositivity are both determined by the topography of the land. Soil properties and surface moisture characteristics are affected by topography [9, 10]. Topography has a significant impact on the spatial distribution of soil properties and influences both endogenic and exogenic soil-forming factors [11, 12]. According to Obi *et al.* [13], incident solar radiation is a function of aspect and slope, which aspect has a significant impact on temperature. As observed by Tsui et al. [14], Sidari et al. [15], as well as Griffiths *et al.* [16], soil chemical processes are influenced by aspect, slope, and elevation as a result of rainfall intensity and incident solar radiation. As noted by Wainright and Brazier [8], slope is referred to as the single most significant aspect of the surface form. Slope angle drives geomorphic processes by influencing water flow rate, colluvial material velocity, and soil infiltration. The landscape's gravitational force is influenced by slope angle. During heavy rains, steeper, longer slopes, especially those without adequate vegetation, are more likely to experience high rates of erosion than slopes with fewer steps. Mudslides, landslides, and other forms of gravitational erosion are more likely to occur in steeper terrain than in floodplains, such as low-lying coastal areas that are prone to flooding [9].

It is worthy to note that apart from the few natural environmental problems, most of the problems threatening our environment are man-made. For instance, even in protected forests, the anthropogenic effects from newly expanding villages, farming, harvesting of medicinal plants, pasturing cattle and forest fires induce environmental modifications, especially on the

forest floor [17]. In essence, most of these activities end up in bringing complications to this fragile ecosystem. When an ecosystem is fragile and highly vulnerable, it has low resistance and is less able to recover and regenerate after determined interference, which results in irreversible changes in the environmental ecosystem [18,19]. This implies that a singular activity carried out in this fragile ecosystem can result in numerous ecological problems. According to Massoli et al. [20] the structure of landscape that suffers from the process of fragmentation is characterized by a mosaic of fragments, or spots which vary in quantity, shape, size, type and heterogeneity, which a times, the said fragments are located in predominantly human interferenced areas. As asserted by Saito [21], expansion of anthropogenic activities intensifies the pressure on areas with natural vegetation resulting in the act of forest fragmentation. According to Blumenfeld et al. [22] there are many researches on the edge effect of forest fragments in which these effects are related to the intensity, types and the physical patterns of forest fragments such as size, layout and format.

However, there are many factors that lead to the high rate of destruction and conversion of natural forest ecosystem to different ecosystems thereby resulting in land surface degradation and other ecological problems [23]. Ecological degradation is a global problem for years; the fallout of this ecological dis-equilibrium results in ecosystem instability especially the fragile forest ecosystem [24,25]. Accordingly, human impacts and global climate changes are the most critical issues on the preservation of biodiversity and conservation of forest ecosystems not only in developing countries but also in developed ones [26, 27]. The rapid population growth in developing countries has increased the demands in forest exploitation in the tropics [26]. As observed by Gillespie et al. [28] ITTO [29], the Nigerian rainforest has been adjudged the most biologically diverse ecosystem on earth. Unfortunately, this important ecosystem is rather appearing in patches, consequence of widespread deforestation [30]. It has been seriously degraded, denuded and destroyed consequences of indiscriminate logging which paved way for other human activities such as farming, sand mining and others culminating into vegetation destruction and land surface alteration [31]. Consequently, the rate of exploitation of natural resources in Nigerian rainforest is alarming as even the forest reserves which are meant to protect endangered species of plant and animal, enrich conservation of timber and soil are not spared. This has brought significant adverse impacts such as deforestation, soil degradation, heavily eroded slopes, siltation of streams and fluvial basins, distortion of valuable wetlands, flood and introduction of various types of pollutants to this sensitive and important ecosystem [32].

However, the objective of this study was to analyse the morphometric traits of SCFR, taking into consideration, the reports of Attah [33], Akpan-Ebe [34]. Ndoho [35] and Umana [36], instigating that SCFR has lost greater part of its vegetation cover due to indiscriminate and uncontrolled anthropogenic activities such as the exploration and extraction of oil and gas, farming, sand mining, lumbering and others. These could negatively affect the land surface of this area, with attendant ecological problems such as erosion, flood and siltation of streams, tributaries and wetlands which formed the basis of this study with the application of digital elevation model (DEM) as a tool for assessment. According to Yacouba et al. [37], elevation and slope information from DEMs can also act as a common-sense role to eliminate the presence or absence of certain classes in some elevation zones.

2. MATERIALS AND METHODS

2.1 Location of the Study Area

Stubbs Creek Forest Reserve (SCFR) which is the study area, situates in the southern part of Akwa Ibom State, between longitudes 7° 59’ E to 8° 16’ E and latitudes 4° 32’ N to 4° 38’ N. (Fig. 1) Its original land area was 310.8km^2 when it was surveyed initially but according to Ndoho [35], its original boundary has been altered extensively giving room to high level of encroachment by communities around it. SCFR has a gently flat surface topography with meandering creeks. According to Usoro [38], the mean altitude of the sand ridge is 30 metres rising to 50 metres at northern boundary. It is surrounded by four (4) local government areas, being Eket, Esit Eket, Ibeno and Mbo (Fig. 1). This Reserve lies within the evergreen low-land rainforest of the Nigerian ecological zone and has two distinct seasons (dry and wet). The vegetation of SCFR is a complex mosaic of abandoned farmlands, regenerating forests, secondary forests, freshwater swamp and mangrove wetlands located within the Niger Delta (Figs. 2 and 3).

The predominant vegetation types are *Mitrogyna stipulosa, Raphia hookeri, Uapaca guineensis, Elaeis guineensis, Xylopia aethiopica, Rhizophora racemosa, Rhizophora mangle, Rhizophora harrisonii, Nypa fruticans, Alstonia boonei,* ferns*, Manihot esculenta* and other food and cash crops.

Geologically, Stubbs Creek Forest Reserve is part of the Niger Delta, which was developed over millions of years because of the Niger and Benue rivers depositing a lot of sediments. The Cretaceous Niger Delta, the Tertiary Niger Delta, the Plio-Pleistocene Niger Delta, and the Late Quaternary Niger Delta make up the geological time sequence [39]. The Continental Benin, Paralic Agbada, and Pro-Deltaic Marine Akata Facies of these Formations were formed in a high-energy constructive deltaic setting [40]. Petters et al. [41] described the physiography of this area as a low-lying coastal/deltaic plains of southeastern Nigeria. It falls among two major landform types of Akwa Ibom State, being the Beach-Ridge Sand characterized by a succession of parallel and sub-parallel sand ridges with a mean altitude of 30 metres rising to 50 metres at its northern boundary of the State as well as the Mangrove Swamp Floodplains with recent Alluvial Accumulations, forming at the estuaries of Cross river in the east and Qua Iboe river in the west (Fig. 3).

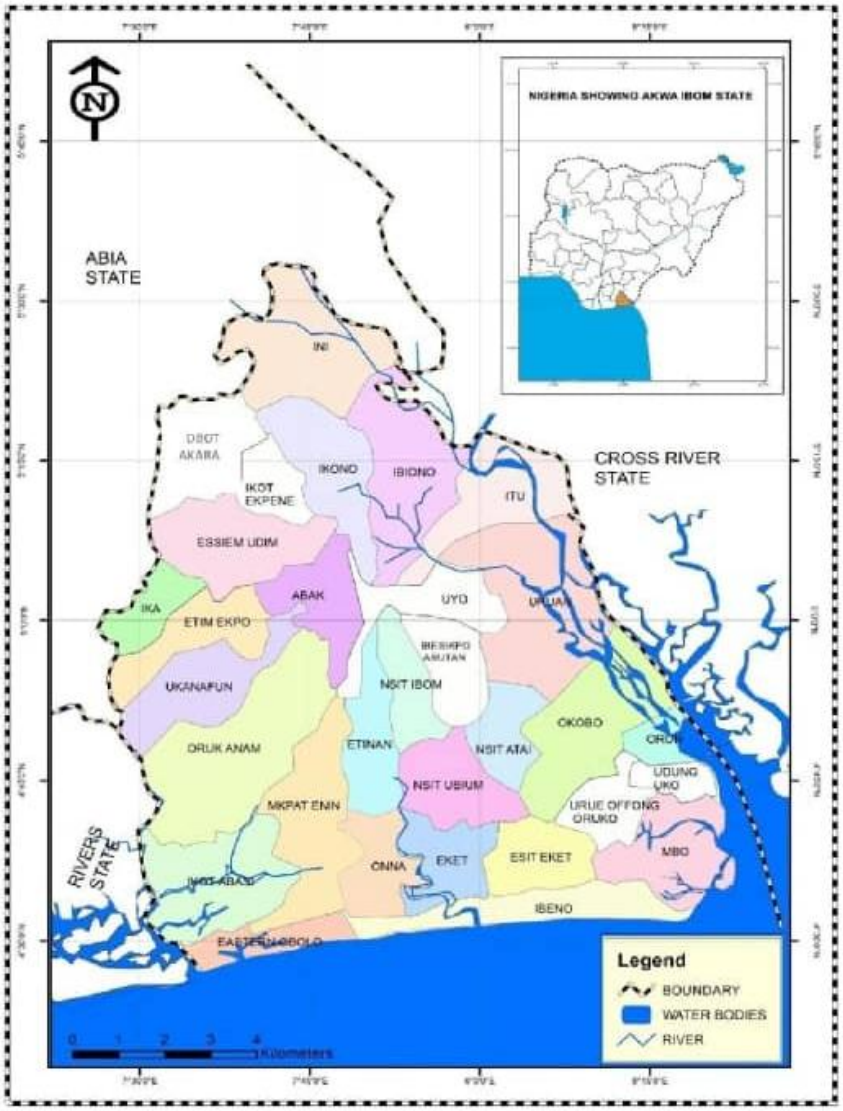

Fig. 1. Map of Akwa Ibom State showing local government areas
Source: Survey Division, Ministry of Lands, Akwa Ibom State

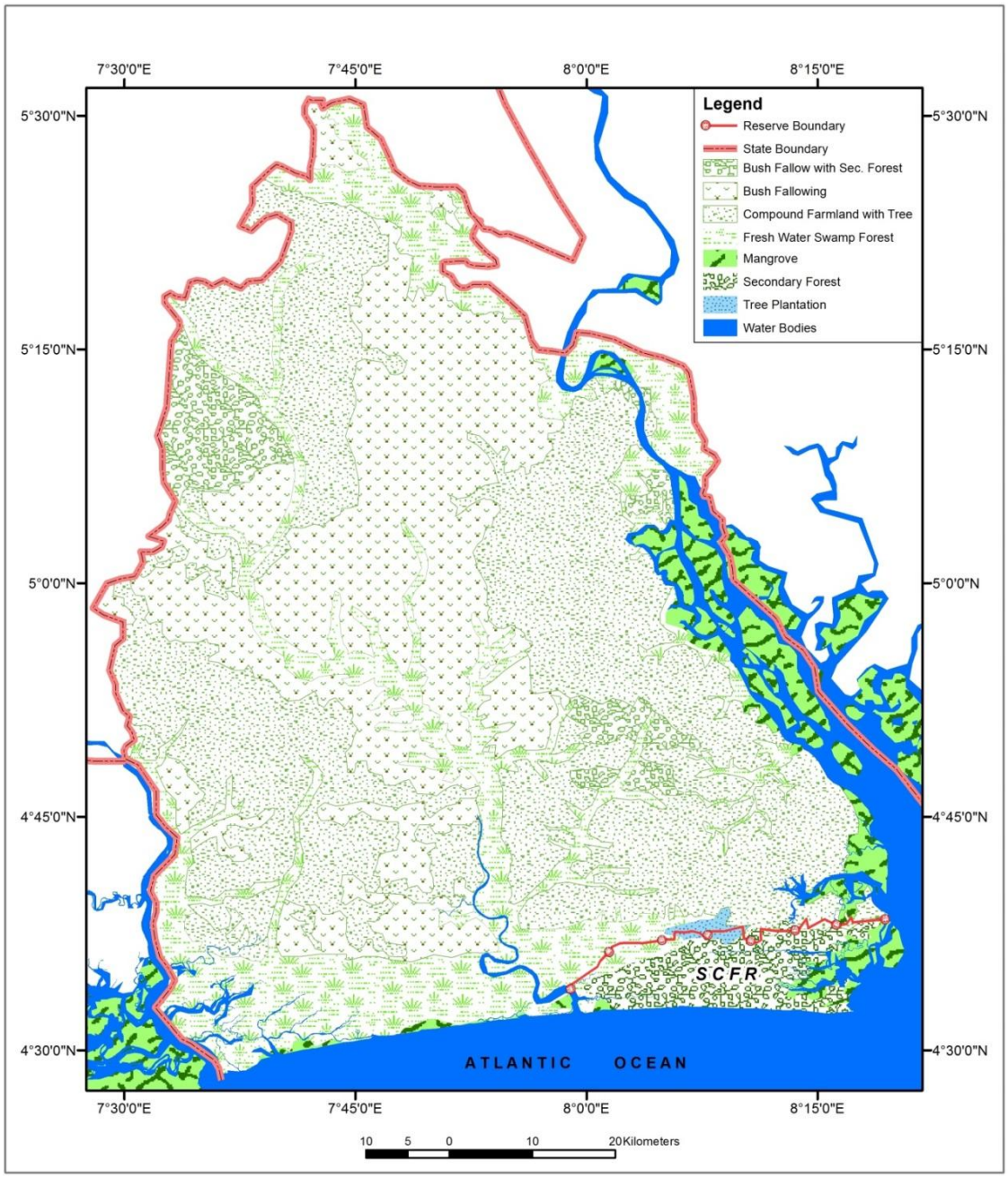

Fig. 2. Map of Akwa Ibom State showing vegetation and study area (SCFR)
Source: Cross River Basin Development Authority.

2.2 Data Acquisition for the Study

A digital elevation model (DEM) was acquired from United States Geological Surveys (USGS) for this study. It was purchased as a raster with longitude and latitude; geo-referenced but re-projected to WGS, UTM zone 32N. This was necessary to enhance data integration into the GIS interfaces. From these layers, the following characteristics of the terrain were derived: (Table 1).

(i) Slope: This was measured in degrees and used as a proxy for ease of water control from 1° through 90° or in percentage. For this study, the slope was calculated in degrees.

(ii) Elevation and general terrain: This was determined as a measure of height

(depth) above (below) as given datum; in this case mean sea level. This is a surface characteristic which largely helps in understanding the possibilities of anthropogenic activities within an area.

(iii) Aspect: The aspect which is measured in degrees from 0° (due north) to 360° in a clockwise direction is an indication of slope face/ direction. This has important information on solar illumination [42] and therefore the amount of insolation for each location, vegetation characteristics, wind and so on. In this study, slope-face was used to indicate the direction of transportation of eroded materials as well as depicting areas likely to experience accretion (Fig. 4).

2.3 Method of Data Analysis

(a) The surface operation tool of ArcGIS 9.3 spatial analyst extension was used to extract the different surface layers being elevation, slope and aspect. These were however subjected to reclassification function in the same software. This was done to harmonize the units of measurement for integration into the same analysis environment. After reclassification, the layers were taken to the map algebra environment to model erosion and flood hazards and the possibility of siltation of tributaries, streams and wetlands within the study area.

(b) Map Algebra: Slope, elevation and aspect were the surface layers utilized for the single output map algebra. In this environment, 30% of both slope and elevation layers were used for the final model while 40% was used for aspect. The percentages varied with the relative importance of each layer in determining the surface characteristics.

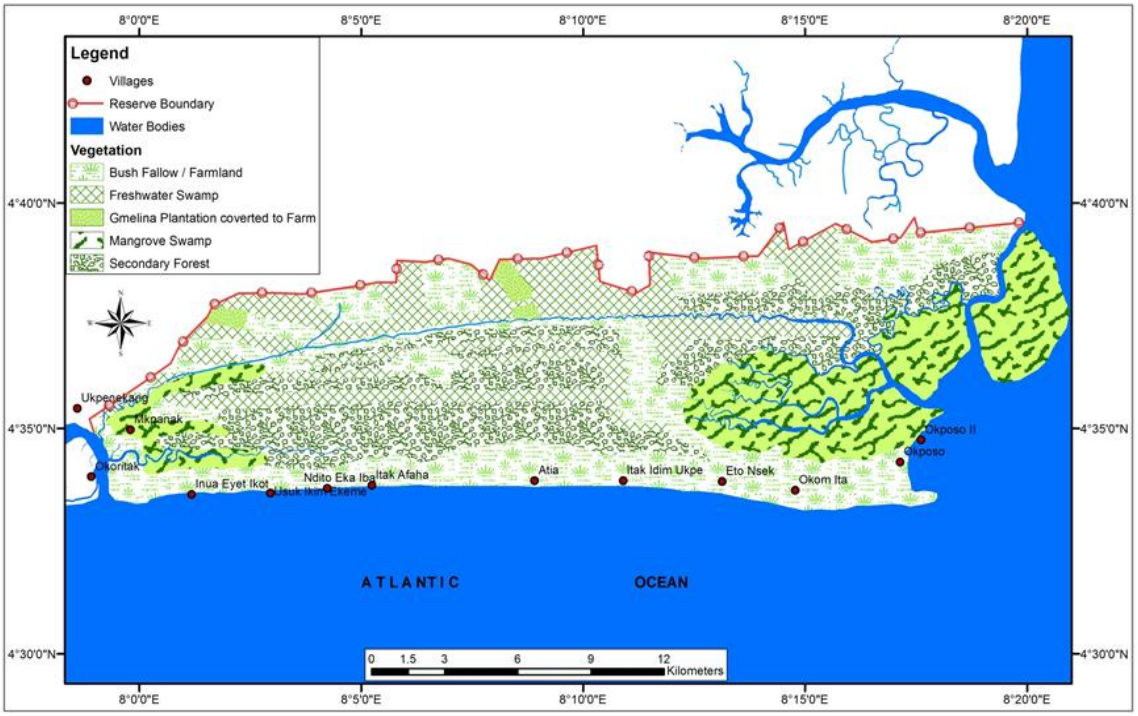

Fig. 3. Map of Stubbs Creek Forest Reserve showing vegetation, settlements and water bodies.
Source: Researchers' field work (2022)

Table 1. Layers showing terrain characteristics determined in SCFR

S/N	Layers	Source	Unit
1	Elevation	DEM	Height in metres (m)
2	Slope	DEM	Degrees (°)
3	Aspect	DEM	Direction (due north)

Source: Researchers' fieldwork (2022)

3. RESULTS

The result revealed the following terrain classes being Open Water, Sea Level Terrain, Beach Ridge Complex, Alluvial Plain Sands with Mangroves and Gently Undulating Plain Sands (Fig. 4). Discussed here under are these distinct terrain classes, exception of Open Water.

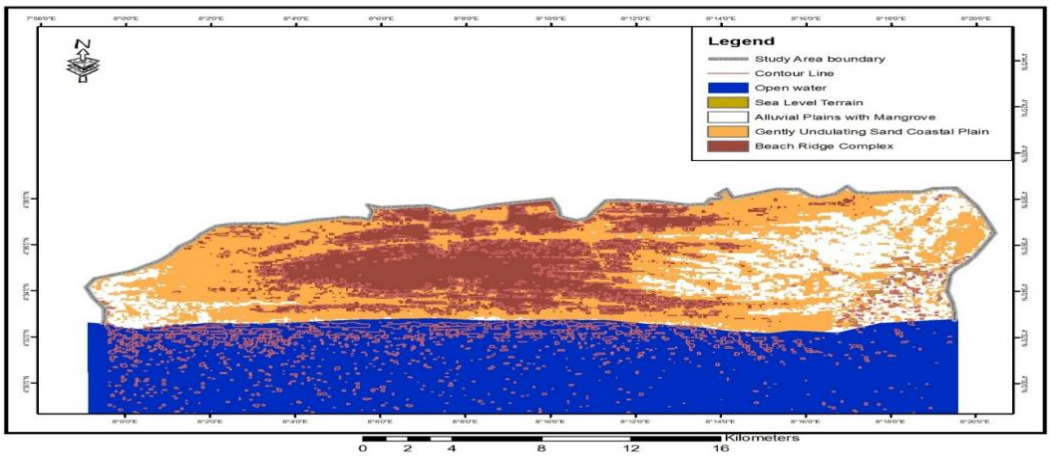

Fig. 4. Stubbs Creek Forest Reserve showing terrain classes
Source: Geographic Information Systems (GIS) Laboratory, UNIUYO (2022)

Fig. 5. Sand mining site within the beach ridge complex environment in SCFR culminating into surface scars, gullies, and siltation of streams and wetlands
Source: Researchers' Fieldwork (2022)

Fig. 6. A sand mining site within the beach ridge complex environment in SCFR culminating into flooding, erosion and siltation of streams and wetlands
Source: Researchers' Fieldwork (2022)

(i) Sea Level Terrain

The Atlantic Ocean shoreline (a surf sandy beach) is more than 200 metres wide, especially in the Ibeno area. This terrain class extends from the estuaries of the Imo river in the west to those of the Cross river in the east. The waves beat the aspect of the beach, sloping gently between 5° and 10° into the open ocean. The beach has a good instinct for tourist attractions including ExxonMobil Oil Terminal, Gulf resort and relaxation facilities at Ibeno axis. The long stretch of the sandy beach here has been utilized by the locals for road transportation outside the water transportation this terrain is noted for. The outstanding ecological problem experienced here was that the ocean continued to expand and claim the land, mostly because of abrupt anthropogenic activities near the shorelines (Fig. 3).

(ii) Beach Ridge Complex

The Beach Ridge Complex covers most parts of Eket, Ikot Abasi and part of Oron Local Government Areas. Just northward of the shoreline to about 10 kilometres inland is a strip of land characterized by a succession of parallel land, sub-parallel ridges of recently deposited marine sands as explained by Usoro [38]. East of Upenekang, the sand ridges are remarkably straight, and up to 400 metres in width. Okorote area is also characterized by straight sand ridges. The mediating swales are reflected in major lineation of vegetation of thick raffia shrubberies which contrasts especially from the spare scrub on the sand edges. The mean amplitude of the sand ridge is 30 metres rising to 50 metres at its northern boundary [41,38]. According to Usoro [38] farming and other activities which expose the land cover to ecological problems should be restricted on the sand ridges ban. This terrain type is very predominant in the study area. It is dissected in a north-south direction by the Stubbs and Widenham creeks as shown in Fig. 4. As indicated in Figs. 5, 6 the incessant and indiscriminate anthropogenic activities such as farming and sand mining in the Edo, Esit Eket axis of the study area had led to the pulled. away effect of the mined sand thereby resulting in ecological problems such as surface scars, erosion, gullies, siltation of streams, rills, tributaries, wetlands and habitat fragmentation (Figs. 6 and 9).

(iii) Alluvial Plain Sands with Mangroves

The Akwa Ibom State's coastal and estuarine areas were largely developed from the alluvial plain sands with mangrove swamps [38]. At Ikot Abasi, the mangrove forest expands at an extremely rapid rate into the Imo river estuary and floodplains; Eket floodplains and the Cross river estuary at Oron are examples. There are enormous parcels of mangrove wetlands landscape qualities around Oron and Mbo regions (Figs. 4, 7). The mangrove swamps are located on tidal flats that are punctuated by tidal channels and winding waterways that are more than 20 metres wide. Usoro [38] found that small meandering creeks developed as strong branches of the main channels in this area. This is common in the east of the Imo river, where a complicated network of channels had created a "jigsaw" of tidal flats of different shapes. Mangrove development in the vicinity of James Town, Okposo, Ebughu, and Oron exhibits similar characteristics. Generally, mangrove forest is predominant here. The soils here are predominantly mangrove soils and beach ridge sand with very low elevation [38].

During the researchers' fieldwork, it was observed that the terrain characteristics of SCFR around Cross river estuary was liable to flooding (Figs. 4 and 7). In essence, the whole of the east front of this area was inundated. Accordingly, the same flood scenario dominated the west end of SCFR, in which there had been incessant exploitation of *Rhizophora* species utilized mainly for fish drying and hot drinks (ufofop) distilling. This has created room for foreign bodies to intrude into this sensitive environment as well as other ecological problems such as habitat destruction, enrichment of heavy metals and soil contamination (Fig. 7).

(iv) Gently Undulating Coastal Plain Sands

In this area, rivers are few and far apart on the sandy plains and their interfluve areas are broad [38]. Shallow depressions and numerous shallow dry valleys are landforms that characterize this area. The land cover here is predominantly secondary forest/bush fallow, while the soil is mainly of beach ridge sand (Fig. 4).

In the southernmost part of the study area, most of the settlements here were threatened by coastal erosion (Figs. 3 and 9). Such settlements include Inua Eyet Ikot, Ndito Eka Iba, Atia, Itak Afaha, Ine Akpautong, Eto Esek, Okom Ita,

Okposo and others. This makes development very difficult in spite of the oil-rich economy of this area. As observed during the researchers' fieldwork, areas where vegetation was cleared for either, road construction, farming and so on were prone to erosion resulting in land degradation, siltation of streams, tributaries, wetlands and habitat fragmentation (Fig. 8).

Fig. 7. A degraded alluvial plain environment in the study area prone to flooding
Source: Researchers' Fieldwork (2022)

Fig. 8. A typical eroded and flooded area in SCFR
Source: Researchers' Fieldwork (2022)

Fig. 9. An eroded point in SCFR leading to land degradation, siltation of streams, tributaries wetlands and habitat fragmentation
Source: Researchers' Fieldwork (2022)

4. DISCUSSION

The result of this study revealed remarkable changes in the land surface of this area. For instance, there was outstanding ecological problem experienced in the Sea Level Terrain environment as the ocean continued to expand and claim the land, mostly because of abrupt anthropogenic activities near the shorelines. This finding is in line with Ituen et al. [43] whose work examined the shoreline changes in this area, which the outcome showed that the shape and length of the Ibeno shoreline had changed drastically. In this regard, the shoreline was measured to be 46.162 km in 1986, 45.811 km in 2006, and 45.94 km in 2008, with different images. This report is in agreement with Efe and Tagi's [44] findings; Scott et al. [45], Liu and Jezek [46], in their respective studies. In terms of data requirements for assessing and monitoring the coastal environment, Ituen et al. [43] had set the standard for data management and timely information delivery regarding Ibeno shoreline activities. For the Beach Ridge Complex Terrain, anthropogenic activities in this area, have brought severe environmental problems such as land degradation, soil nutrient loss, erosion, surface scars, gullies, siltation of streams, rills, tributaries, habitat fragmentation and distortion of wetlands. Equally, the incessant and indiscriminate anthropogenic activities in this area have resulted in the pulled-away effect of the fragile sand of this area. Apart from the ecological problems, destruction of vegetation for logging, ranching, farming, mining and others also lead to carbon dioxide emissions. According to Srivastava [47], when vegetation dies or burns, it releases carbon dioxide. It is observed that regrowth would replace the lost vegetation with little or no net carbon dioxide emissions [47].

Consequently, Alluvial Plain sands with Mangroves is one of the terrains in this area threatened by deplorable ecological problems such as flood, habitat fragmentation, erosion and soil contamination. Coastal flooding is one of the ecological problems affecting this terrain class as reported by Usoro [38]. This area has a gently flat surface and is criss-crossed by numerous creeks mostly at the eastern and western ends, which make larger part of it inundated in most parts of the year. More so, this area has lost a greater amount of its vegetation, especially *Rhizophora* species thereby subjecting it to severe ecological threats such as flood and so on as shown in Figs. 4 and 7. This is in agreement with Ekpenyong et al. [48] who asserted that only a few stands of mangrove species namely: *R. racemosa* and *A. Africana* were found in the Cross river and Qua Iboe river estuaries. This means that so much has been lost over the years resulting in mangrove deforestation. The result is that areas that had mangroves some years ago have been taken over by *Nypa fruticans* (Fig. 7), which is in line with the works of David et al. [49]; Ogar et al. [50] and Abraham et al. [51] who reported that mangrove swamp forests in the coastal part of Akwa Ibom State were gradually shrinking, thus paving way for intense environmental problems. A typical illustration of this is the frequency and intensity of persistent stream and drainage in such locations, which indicate that surface runoff is not quickly removed from the basins, making it susceptible to flooding and creating a marshy environment [5]. Above all, the Gently Undulating Coastal Plain Sands environment recorded a series of ecological problems such as erosion, water pollution, siltation of streams, rills, tributaries and habitat destruction (Figs. 8, 9). As observed by Abraham et al. [51], coastal erosion has had an influence on the mangrove ecosystem, and fishing settlements of Akwa Ibom State. For example, Ibeno Beach, Eastern Obolo, Oron, and Ikot Abasi, as well as other coastal areas, have been severely eroded, leaving behind piles of debris along channels and open spaces. This has rendered the people in deplorable conditions and reduced agricultural and economic development in this area [52,53]. In agreement with this study, Ituen et al. [43] observed that within the period of their study on the Ibeno shoreline change detection, 147.07 m was the highest accretion value while 0.5 m was the lowest. Their report revealed that the damage done to buildings and trees respectively caused more eroding than accreting areas across the entire shoreline. For instance, Itak Abasi fishing settlement along this shoreline had been adversely affected and had jeopardized the socio- economic activities of the people in this area.

5. CONCLUSION

The study revealed that virtually, all parts of SCFR were threatened by ecological problems due to incessant and indiscriminate anthropogenic activities. Coupled with the low-lying elevation of this area, with loose sand texture, the land surface recorded significant degradation, and most areas were either submerged or washed away by water currents, most especially where vegetation had been

cleared. This has affected the ecological regime of this area and resulted in adverse environmental and ecological problems such as flood, erosion, water pollution, soil contamination and siltation of streams, rills, tributaries, wetlands and habitat fragmentation. It is hereby recommended that anthropogenic activities should be restricted in this area. Above all, adequate remediation and restoration measures should be applied to restore affected areas in SCFR for its sustainability.

AVAILABILITY OF DATA AND MATERIAL

All the needed data are available in this manuscript and have electronic supporting information (ESI).

FUNDING

This research was not funded by any governmental or non-governmental agency.

ETHICAL APPROVAL

A number of ethical issues bothering this research were addressed. Prior to the assessment of the land use data of SCFR, a letter of consent was dispatched to the Forestry Directorate of the Ministry of Environment and Solid Minerals, Akwa Ibom State indicating the nature, purpose and concept of the research which due permission was given to carry out the study. Also, major stakeholders within the study area were consulted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Reddy OGE, Maji AK, Gajbhiye KS. GIS for morphometric analysis of drainage basins. GIS India response to land use change in the middle and upper reaches of the Heihe River Basin. 2002;11(4):9-14.
2. Rao LAK, Yusuf A. Morphometric analysis for soil erosion assessment in parts of Chambal basin using remote sensing and GIS Madhya Pradesh. IJATER ISSN No. 2250 – 3536. 2013;3(3):134 – 141
3. Biswas IA, Biswas ZM. Morphometric land use and land cover change analysis of Lokjuriya River Basin Jharkhand India using remote sensing and GIS. 10SR Journal of Humanities and Social Science (IOSR – SHSS). 2015;20(7):77 – 85.
4. Enokela OS, Iorkyar TT, Kwadzah TK. Assessment of the morphomerty of gullies in Katsina-Ala Nigeria. Journal of Environment and Earth Science. 2013;3(8):41-46.
5. Eze BE, Effiong J. Morphometric parameters of the Calabar River Basin: Implication of hydrologic processes. Journal of Geography and Geology. 2010;2:18-26.
6. Ezenwaji EE, Nwabineli EO, Phil-Eze PO. Investigations into the morphometric characteristics of Obibia Drainage Basin Awka Urban Area Nigeria. Open Journal of Modern Hydrology. 2018;8:1-12.
7. Pal SC, Debnath GC. Morphometric analysis and associated land use study of a part of the Dwarkeswar watershed. Internal Journal of Geometrics and Geosciences. 2012;3(2):351-362.
8. Wainright J, Brazier RE. “Slope systems”. In Thomas David S. G. Arid Zone Geomorphology Process. Form and change in dry lands. John Wiley and Sons; 2011.
9. Seibert J, Stendahl J, Sorenson R. Topographical influences on soil properties in boreal forests. Geoderma. 2007; 141:139-148.
10. Behrens T, Zhu AX, Schmidt K, Scholten T. Multi-scale digital terrain analysis and feature selection for digital soil mapping. Geoderma. 2010;155:175-185.
11. Schaetzl RJ, Anderson SN. Soil genesis and geomorphology. Cambridge University Press Cambridge Uk; 2005.
12. Debella-Gilo M, Etzelmuller B, Klakegg. Digital soil mapping using digital terrain analysis and statistical modeling integrated into GIS: examples from Vestfold country of Norway. Proceedings ScanGIS’2007. 2007;237-253.
13. Obi JC, Ogban PI, Ituen UJ, Udoh BT. Development of pedotransfer functions for coastal plain soils using terrain attributes. Elsevier. Catena. 2014;123:252-262.
14. Tsui CC, Chen ZS, Hsieh CF. Relationships between soil properties and slope position in a lowland rain forest of southern Taiwan. Georderma. 2004;123 131-142.
15. Sidari M, Ronzello G, Vecchio G, Muscolo A. Influence of slope aspects on soil chemical and biochemical properties in a

Pinus laricio forest ecosystem of Aspromonate (Southern Italy). Eur. J. Soil Biol. 2008;44:364-372.
16. Griffiths RP, Madritch MD, Swanson AK. The effect of topography on forest soil characteristics in the Oregon Cascade Mountains (USA): implication for the effects of climate change on soil properties. For. Ecol. Manag. 2009;257:1-7.
17. Ananya P. Thares S. Somboon K. Jin Y. Atsushi I. Masae S. Takehiko M. Prenom C. Somkid O. and Issara P. Scientific Reports. 5:14689. DOI:10.1038/srep14689.
18. Liao X, Li W, Hou J. Application of GIS based ecological vulnerability evaluation in environmental impact assessment of master plan of coal mining area. Procedia Environmental Science; 2013. DOI:https ://doi.org/10.1016/j.proen v. 2013.04.035
19. Macedo DR, et al. Development and validation of an environmental fragility index (EFI) for neotropical savannah biome. Science of the Total Environment; 2018. DOI:https ://doi. org/10.1016/j.scito tenv.2018.04.216
20. Massoli JV, Statella T, Santos VS. Forest fragmentation assessment on the Sepotubinha Drainage Basin Nova Marilandia – MT: Ranging from the year 1990 to 2014. Rev Caminhos de Geografia; 2016. DOI:https ://doi.org/10.14393 /RCG17 6004
21. Saito NS, et al. Geotecnologia e Ecologia da Paisagem no Monitoramento da Fragmentacao Florestal. Floresta e Ambiente; 2016. DOI:https://doi.org/10.1590/2179-8087.119814
22. Blumenfeld EC, Santos RF, Thomaziello SA, Ragazzi S. Relationship between neighborhoods matrix and the edge effects in a forest fragment. Ciencia Florestal; 2016. DOI:https ://doi.org/10.5902/19805 09825 150
23. Burford G. Bodeker G, kabalesi D, Grmnil B, Rukangira E. Traditional medicine and HIV/AIDS in Africa. Journal of Alternative and Complementary Medicine. 2001;6:457-472.
24. Liberty J Ugwushiwu B Bassey G, Eke V. Effects of natural resources utilization on the ecosystem and its remedies in Nigeria. International Journal of Scientific and Engineering Research. 2013;4(8):2229-5518.
25. Milupi I, Somers M, Ferguson W. A review of community-based natural resource management. Applied Ecology and Environmental Research. 2017;15(4):1121-1143.
26. FAO FAO Statistical Databases. Food and Agriculture Organization Rome Italy; 2005.
27. Nowacki GJ, Abrams MD. Is climate an important driver of post-European vegetation change in the Eastern United State? Global Change Biol. 2015;21:314-334.
28. Gillespie TW, Brack J, Wright CW. Prospect of quantifying structure Floristic composition and species richness of tropical rainforest. International Journal of Remote Sensing. 2004;25(14):70-77.
29. ITTO (International Tropical Timber Organisation). Status of tropical forest management. Tropical Forest Update. 2011;20(3):1-27.
30. Akpan-Ebe IN. Reforesting the tropical rainforest in south-eastern Nigeria. Nigerian Journal of Agriculture Food and Environment. 2015;10(4):128-134.
31. Olajide O, Etuk IM, Essien CJ. Ecological and phytosocio-economic assessment of undergrowth in a community-owned rainforest reserve in Akwa Ibom State Nigeria. International Journal of Agricultural Research and Food Production. 2019;4(2)1-8.
32. Ajah PO. Environmental conservation and ecological foundation. Jerry Commercial Productions Calabar. 2006;346.
33. Attah VI. Problems of sustainability the Stubbs Creek Forest Reserve Akwa Ibom State. Journal of Nigerian Environmental Society. 2003;1(1).
34. Akpan-Ebe IN. Gap-phase dynamics and natural regeneration in the Stubbs Creek Forest Reserve of Akwa Ibom State Nigeria. PhD Thesis University of Ibadan Nigeria; 2005.
35. Ndoho JT. Exploitation of biodiversity in Stubbs Creek Forest Reserve Akwa Ibom State Nigeria. Ph.D Thesis carried out in the Department of Geography and Regional Planning University of Calabar Calabar Nigeria; 2009.
36. Umana US. Anthropogenic activities on the ecosystem components of Stubbs Creek Forest Reserve Akwa Ibom State Nigeria. Ph.D Thesis carried out in the Department of Geography and Natural Resources

Management University of Uyo Uyo Nigeria; 2021.
37. Yacouba D, Guangdao H, Xingping W. Assessment of land cover changes using Ndvi and DEM in Puer and Simao countries Yunkan Province China Report and Opinion Journal. 2010;2(9):1-15.
38. Usoro EJ. Relief: In Akwa Ibom State: A geographical perspective. A special publication of the Department of Geography and Regional Planning University of Uyo Nigeria. Immaculate Publications Ltd, Enugu. 2010;16-22.
39. Whiteman A. Nigeria: Its petroleum geology resources and potential. 2 volume Graham and Trotman. 1982;392.
40. Wright JB, Hastings DA, Jones WB, Williams HR. Geology and mineral resources of West Africa. George Allen and Urwin Publication. London. 1985;187.
41. Petters SW, Usoro EJ, Udo EJ, Obot UW, Okpon UW, Okpon SN. Akwa Ibom State physical background soils landuse and ecological problems. Technical Report of the Task Force on Soils and Landuse. Government Printer Uyo. 1989;602.
42. McCoy J, Johnston K. Using ArcGIS spatial analyst. GIS by ESRI USA. 2001;147-157 and 189-199.
43. Ituen UJ, Johnson IU, Njoku JC. Shoreline change detection in the Niger Delta: A case study of Ibeno Shoreline in Akwa Ibom State Nigeria. Global Journal of Human-Social Sciences. 2014; XIV:VI.
44. Efe, Tagil. The use of multi-temporal and multi-spectral landsat data to determine change detection around Tuz Lake on Seyhan Delta. Fresenius Environmental Bulletin Parlar Scientific Publications; 2001.
45. Scott JW, Moore LR, Harris WM, Reed MD. Using the landsat 7 enhanced thematic mapper tasseled cap transformation to extract shoreline. U. S. Geological Surveys Report. 2003;03-272.
46. Liu H, Jesek KC. Automated extraction of coastline from satellite imagery by integrating canny edge detection and locally adaptive thresholding methods. International Journal of Remote Sensing. 2004;25:937-958.
47. Srivastava. A least-squares approach to improve shoreline modelling. M.Sc Thesis (Published) Ohio State University. 2009;1-4.
48. Ekpenyong RE, Ukpong I, Olajide S, Etuk I, Ebong M, Etim ER. Geospatial analysis of the distribution of mangrove species along the shoreline in Akwa Ibom State Nigeria. Journal of Geography Environment and Earth Science International. 2018;18(3):1-22.
49. David U, Ndukwu B, Obafemi A. Perception assessment of the impact of human activities on Stubbs Creek Forest Reserve Akwa Ibom State. Scientific Resources Publishing. 2019; 10(5):139-152.
50. Ogar DA, Asuk S, Umanah I. Forest cover change in Stubbs Creek Forest Reserve Akwa Ibom State Nigeria. Applied Tropical Agriculture. © A publication of the School of Agriculture and Agricultural Technology the Federal University of Technology Akure Nigeria. 2016;21(1):183-189.
51. Abraham CM, Evelyn PA, Eyo EE, Ibanga IJ, Ebong MS, Jimmy UJ, Udo WM, Umana SU. Assessment of ecological degradation and associated implications in Southern Akwa Ibom State: Why actions need to be taken. Journal of Ecology and Natural Resources. 2021;5(2):1-15.
52. Abraham C. Implications of gully development on agricultural production in Akwa Ibom State: An Unpublished Ph.D Thesis Department of Geography and Regional Planning University of Uyo Akwa Ibom State Nigeria; 2010.
53. Abraham C, Wilcox R, Anthony P. Assessing gully erosion menace and efforts at amelioration in Itu Akwa Ibom State Nigeria. Book of Proceeding; Environmental Management Association of Nigeria (Eman) 2014 Annual Conference-Le Meridian Hotel and Golf Resort. 2014b;379-391.

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